Data Driven Sustainable Development Measurement: Empirical Case in Selected Countries

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Abstract

In this paper, the author examined Environmental Kuznet curve in some selected Southeast Asia Countries. This study empirically investigates the existence or not of Environmental Kuznets Curve (EKC) hypothesis in some Southeast Asia countries, with carbon dioxide emissions as proxy of environmental quality. The data are gathered from the years 2000–2021 and covering five countries. Using the Gross National Income per capita as measure of economic growth, we show only Singapore had reached EKC reverse U curve. Meanwhile, the author adapted the equation from Tchouto, J.E.T., 2023 and Peterson, A., & Sachs, J.,2000. The results are varied by countries.

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Research Background

This research aims to explore the background of sustainable development measures concerning a country's CO2 and Gross National Income (GNI) per capita. It seeks to investigate the impact of different recovery strategies on sustainable economic recovery in nations with varying income levels, shedding light on the effectiveness of these measures in fostering post-pandemic economic resilience and growth.

Furthermore, the study will delve into the relationship between some independent variables, namely foreign direct investment (FDI) and research and development (R&D) expenditure as a percentage of gross domestic product (GDP) and GNI per capita, and ECI (Economic Complexity Index) in the context of development. FDI, representing capital inflows from foreign investors, signifies confidence in a country's economic potential and its attractiveness for international investments. R&D expenditure, on the other hand, reflects a nation's commitment to innovation and technological advancement, which are critical for long-term economic development and competitiveness. The author uses GNI per capita as a measurement of income per capita. The author approach differs from the others because we are using Gross National Income (GNI) per capita instead of other measure of economic growth (Tchouto, J.E.T., 2023). For the purpose of measuring economic sophistication, the author used the ECI as economic complexity index (Tchouto, J.E.T., 2023; Jaffe, K., Ríos, A. and Florez, A., 2012).

Additionally, it is anticipated that higher levels of FDI and R&D expenditure, as a percentage of GDP, will exhibit a positive correlation with stronger economic recovery post-pandemic, highlighting the crucial role of foreign investment and innovation in shaping a country's recovery trajectory (Ghosh, T. and Parab, P.M., 2021). Foreign direct investment (FDI) plays a vital role in the economic recovery of countries post-pandemic (Ghosh, T. and Parab, P.M., 2021). FDI involves a company from one country making a physical investment in another country, such as building a factory or acquiring a business. These investments can stimulate economic growth, create job opportunities, and enhance productivity.

Research and development (R&D) expenditure as a percentage of GDP is another crucial factor in development measurement (Ghosh, T. and Parab, P.M., 2021, Park, J., 2012). Countries that invest a significant portion of their GDP in R&D activities tend to be more innovative and competitive in the global market. Increased R&D expenditure can lead to the development of new technologies, products, and services, which can drive economic growth and improve productivity. This, in turn, can positively impact per capita income by creating new opportunities for consumers and businesses.

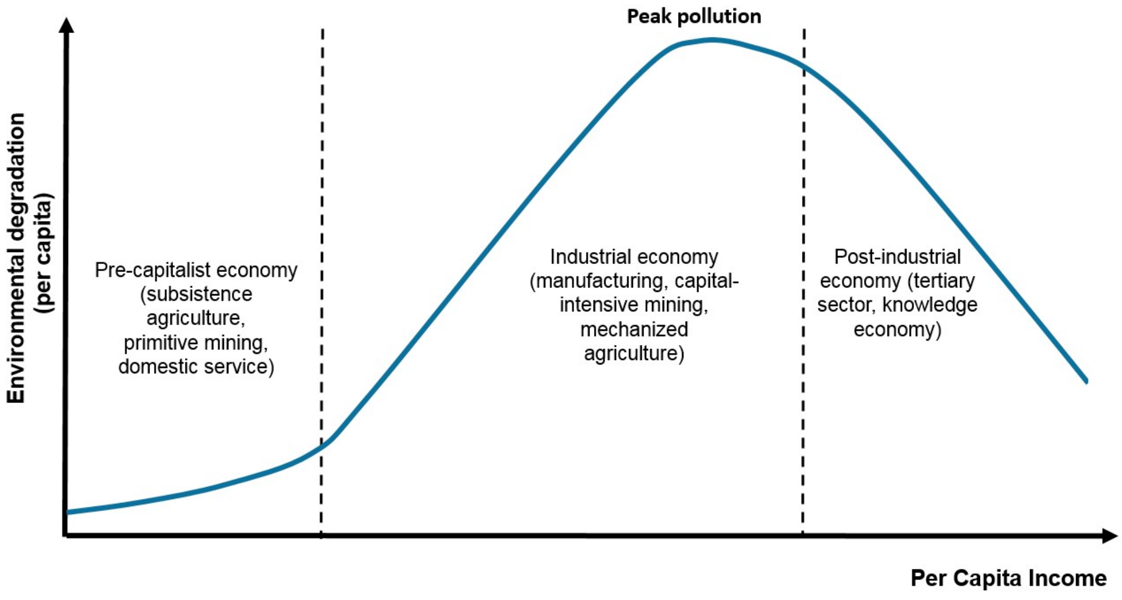
Methodologically, this research will employ a comprehensive analysis approach, examining data from a diverse set of countries with varying GNI per capita levels to assess the relationship between GNI per capita as one of the efficacies of sustainable development measures. Furthermore, the study will investigate the influence of FDI and R&D expenditure on economic recovery, providing valuable insights into the factors that drive economic resilience and growth following the COVID-19 pandemic. Furthermore, ECI included in this analysis to measure economic sophistication (Tchouto, J.E.T., 2023). Finally, CO2 is a measurement to examine sustainable growth in the green economics context (Tchouto, J.E.T., 2023; Sadik-Zada, E.R. and Ferrari, M., 2020; Petrović, P. and Lobanov, M.M., 2020 Panayotou, T., Peterson, A., & Sachs, J.,2000).

The findings of this study are expected to offer significant contributions to the existing knowledge base on the economic implications of the COVID-19 pandemic and the determinants of post-pandemic recovery. Through a nuanced understanding of how CO2, GNI per capita, FDI, and R&D expenditure, and ECI, impact economic recovery, policymakers, economists, and international organizations can develop tailored strategies to navigate the challenges and opportunities presented in the post-COVID world.

Ultimately, this research seeks to provide comprehensive insights into the factors that shape sustainable post-COVID economic recovery, informing policymakers, researchers, and stakeholders on the dynamics at play in reconstruct and revitalizing economies in the aftermath of the global health crisis. To summarize, the author used Environmental Kuznets Curve to measure the developmental phase of each country (Tchouto, J.E.T., 2023, Sadik-Zada, E.R. and Ferrari, M., 2020, Panayotou, T., Peterson, A., & Sachs, J.,2000).

Literature review

The environmental Kuznets curve (EKC) is an assumed relationship between several instruments of environmental degradation and income per capita. In the early stages of economic growth, pollution emissions surge and environmental quality declines, but beyond some level of income per capita (which will vary for different instruments) the trend reverses, so that at high income levels economic growth leads to environmental advancement. This indicates that environmental impacts or emissions per capita are an inverted U-shaped function of income per capita. The EKC is named after Simon Kuznets who proposed that income inequality first increases and then falls as economic development proceeds (Stern, D. I.,2018).



Structuralist approach to the environmental Kuznets curve (EKC)

Source: Sadik-Zada, E.R. and Ferrari, M., 2020.

The EKC is an essentially empirical phenomenon, but most estimates of EKC models are not statistically robust. Focuses of some local pollutants have clearly declined in developed countries but there is much less clarity about emissions of pollutants. Investigate of the relationship between per capita emissions and income that attempt to avoid various statistical pitfalls find that per capita emissions of pollutants increase with growing income per capita when other factors are held constant. Nevertheless, changes in these other factors may be sufficient to reduce pollution. In rapidly growing middle-income countries, the effect of growth overwhelms these other effects. In wealthy countries, progress is slower, and pollution reduction efforts can overcome the growth effect. This appears to be the origin of the apparent EKC consequence. These econometric results are supported by evidence that, in fact, pollution problems are being addressed in developing economies. However, there is still no consent on the drivers of changes in pollution (Stern, D. I.,2018).

Towards the 1980s, mainstream environmental thought held that environmental impact increased with the scale of economic activity, though either more or less environmentally friendly technology could be chosen. This approach is represented by the IPAT model proposed by Ehrlich and Holdren (1971). IPAT is an identity given by impact = population affluence technology. If affluence is income per capita, then the technology term is impact or emissions per dollar of income. The 1980s saw the introduction of the sustainable development concept, which contended that, in fact, development was not essentially damaging to the environment and that poverty reduction was essential to protect the environment (WCED, 1987). In line with this sustainable development idea, Grossman and Krueger (1991) presented the EKC concept in their path-breaking research of the potential impacts of the North American Free Trade Agreement (NAFTA). Environmentalist critics of NAFTA claimed that the economic growth that would result from introducing free trade would damage the environment in Mexico. Grossman and Krueger (1991) contended instead that improved growth would actually advance environmental quality in Mexico rather than it reduce. To provision this argument, they carried out an empirical analysis of the relationship between ambient pollution levels in many cities around the world from the GEMS database and income per capita. This examination found that the concentrations of several pollutants peaked when a country got roughly the level of Mexico's per capita income at the time.

The EKC was disseminated by the World Bank's 1992 World Development Report, which depend on research by Shafik (1994). The report contended that: "The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments" (p. 38) and that "As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment" (p. 39). Others have explained this position even more convincingly with Beckerman (1992) claiming that "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich" (p. 482). Nevertheless, Shafik's study showed that both urban waste and carbon emissions did not seem to follow an inverted U-shaped curve. Subsequent research confirmed these findings and has cast doubt on the validity of the EKC hypothesis for emissions of other pollutants too.

Data & Empirical Methodology

The author accommodated the model of Tchouto, J.E.T., (2023), Petrović, P. and Lobanov, M.M. (2020) and Panayotou, T., Peterson, A., & Sachs, J. (2000) which are measure carbon emission as dependent variable. However, in this research, we use carbon emission per capita as we accommodated from Tchouto, J.E.T., (2023) and Panayotou, T., Peterson, A., & Sachs, J. (2000). In these equations, the subset t is a time variable, $CO2_{it}$ is the carbon emissions level per capita, α_0 the scale parameter. ECI_{it} is the Economic Complexity Index in each country, with the idea that this variable can be a significant determinant of CO2 emissions. X_{kt} is a vector of controls variables. α_1; α_2 and δ_3 are the coefficients of Gross National Income (per capita) and Gross National Income (per capita) Square and Economic Complexity Index, and δ_k is a vector of the coefficients of the controls variables which will be determined. The author obtained the data from the World Bank Development Indicator (WDI) and ECI data from Atlas Harvard for the years 2000–2021. This study gathered samples from Indonesia, Malaysia, Singapore, Thailand, and Vietnam. The study adjusted GLS method from Peterson, A., & Sachs, J. (2000) and Tchouto, J.E.T., (2023). The author constructed equation as follows:

$$CO2_{it} = \alpha_0 + \alpha_1 GNI_{it} + \alpha_2 GNI_{it}^2 + \delta_3 ECI_{it} + \delta_k X_{kt} + \varepsilon_{it}$$

CO2 is CO2 emissions (metric tons per capita)
GNI is Gross National Income per capita, Atlas method (current US$)
ECI is Economic Complexity Index

Results and Discussion

The author examined all variable stationarity while all variables had stationer in the first difference then we use 1st difference in the equation.

In sum, the author examined the panel regression as the author adjusted from Peterson, A., & Sachs, J. (2000), Petrović, P. and Lobanov, M.M. (2020) and Tchouto, J.E.T., (2023). The results follow:

All countries (panel GLS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RD)	-0.40527	0.210213	-1.92792	0.057*
D(GNI_PER_CAPITA)	0.000151	6.11E-05	2.469528	0.0154**
D(GNI2)	-1.38E-09	7.35E-10	-1.87203	0.0645*
D(FDI_INFLOWS)	0.0138	0.007409	1.862643	0.0658*
D(ECI)	0.179298	0.159918	1.121188	0.2652
C	0.007114	0.022	0.323379	0.7472

* Sig at .1, ** Sig at .05

Furthermore, the author adjusted model from Paramati et. al (2021) to examined per country specified analysis, the results follow:

per countries (cointegrating regression FMOLS)

Country	Variable	Coefficient	Std. Error	t-Statistic	Prob.
Indonesia	D(RD)	0.057927	0.750494	0.077184	0.9396
	D(GNI_PER_CAPITA)	0.00011	8.48E-05	1.296497	0.2158
	D(FDI_INFLOWS)	0.000159	0.017085	0.009302	0.9927
	D(ECI)	0.498903	0.240572	2.073821	0.057*
Malaysia	D(RD)	-0.64848	0.412466	-1.57219	0.1382
	D(GNI_PER_CAPITA)	0.000344	9.13E-05	3.7656	0.0021**
	D(FDI_INFLOWS)	0.058645	0.033409	1.755386	0.101
	D(ECI)	0.404408	0.479099	0.844103	0.4128
Singapore	D(RD)	-0.21227	0.498628	-0.42571	0.6768
	D(GNI_PER_CAPITA)	2.25E-05	3.42E-05	0.659577	0.5202
	D(FDI_INFLOWS)	0.009434	0.011698	0.806464	0.4335
	D(ECI)	-0.147	0.721412	-0.20377	0.8415
Thailand	D(RD)	-0.6475	0.283297	-2.28558	0.0384**
	D(GNI_PER_CAPITA)	-3.80E-05	0.00011	-0.34578	0.7346
	D(FDI_INFLOWS)	0.031451	0.014317	2.196781	0.0454**
	D(ECI)	-0.08225	0.305314	-0.26938	0.7916
Vietnam	D(RD)	-0.67007	1.058228	-0.6332	0.5368
	D(GNI_PER_CAPITA)	0.000538	0.000407	1.322551	0.2072
	D(FDI_INFLOWS)	0.008262	0.02724	0.303295	0.7661
	D(ECI)	-0.28289	0.305303	-0.9266	0.3698

* Sig at .1, ** Sig at .05

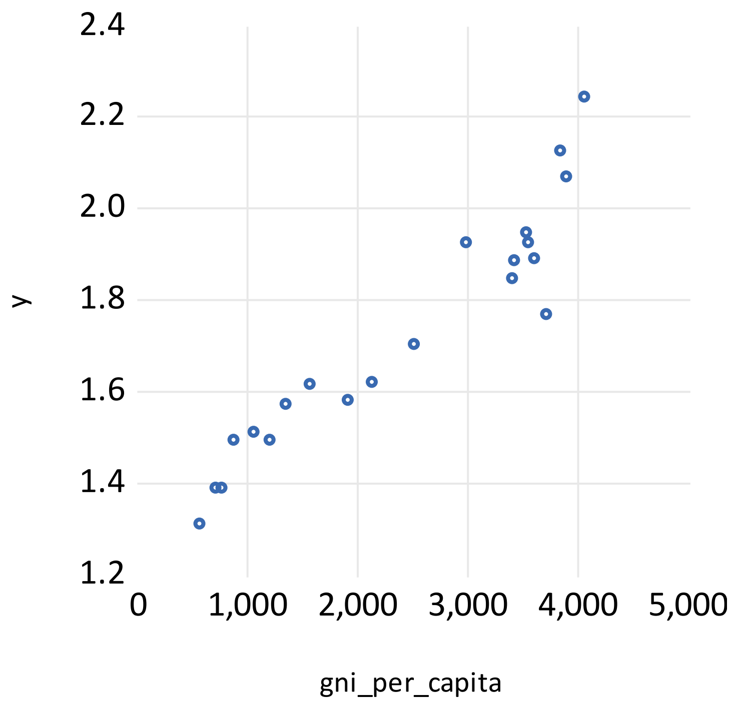
Based on the analysis outcomes, it was determined that Indonesia exhibited a positive coefficient in the Economic Complexity Index (ECI), which was notably associated with carbon emissions per capita. In the case of Malaysia, a positive coefficient was observed in Gross National Income (GNI) per capita, highlighting its significant correlation with carbon emissions per capita. Thailand, on the other hand, displayed a positive coefficient significant in foreign direct investment (FDI) inflows, indicating a meaningful relationship with carbon emissions per capita. Additionally, Thailand showed a negative coefficient significant in research and development (R&D) regarding to reduce carbon emissions per capita. The prevalence of negative R&D coefficients across majority of these countries suggests that there may be untapped potential for leveraging research and innovation to mitigate carbon emissions effectively. By emphasizing investments in green technologies and sustainable practices, these nations can work towards reducing their carbon footprint and fostering environmentally friendly economic growth. Prioritizing research and development initiatives focused on sustainability can play a pivotal role in driving down carbon emissions and promoting a more sustainable future for these countries and the planet as a whole.

Further Analysis: Environmental Kuznet Curve

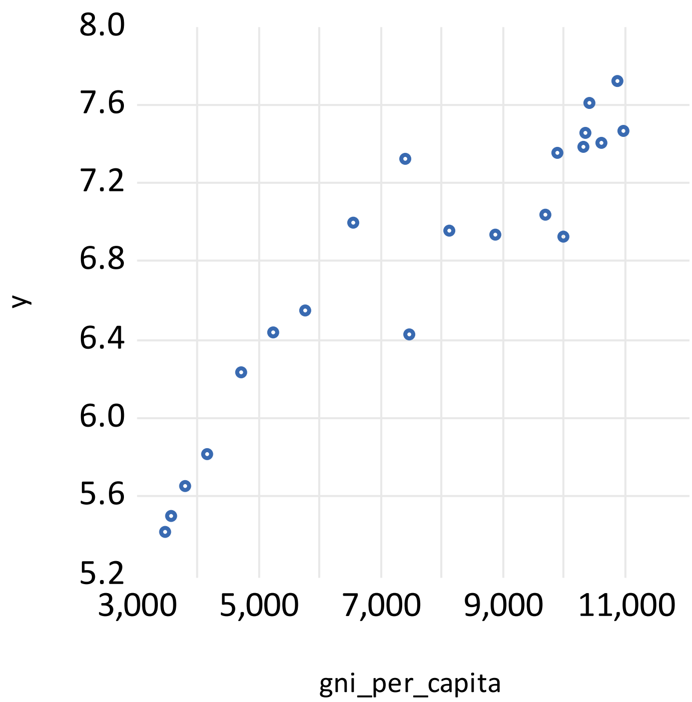
Environmental Kuznet Curve Graphic

In the final step, the author examined the Environmental Kuznet Curve in the selected countries. The results follow:

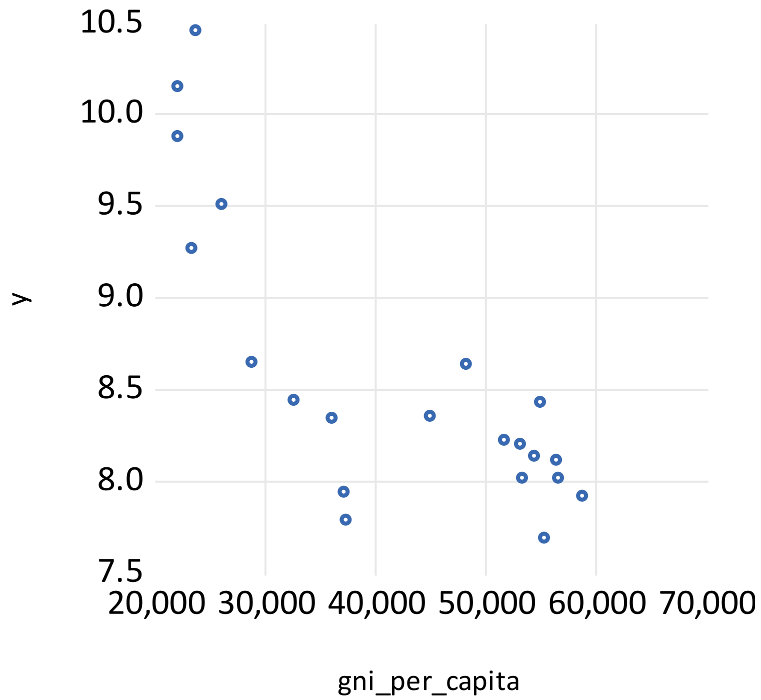
Indonesia



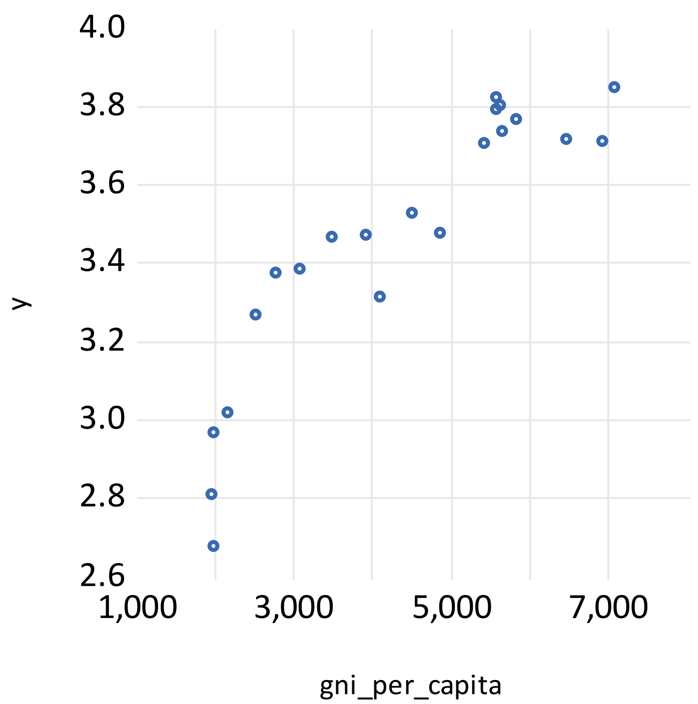
Malaysia



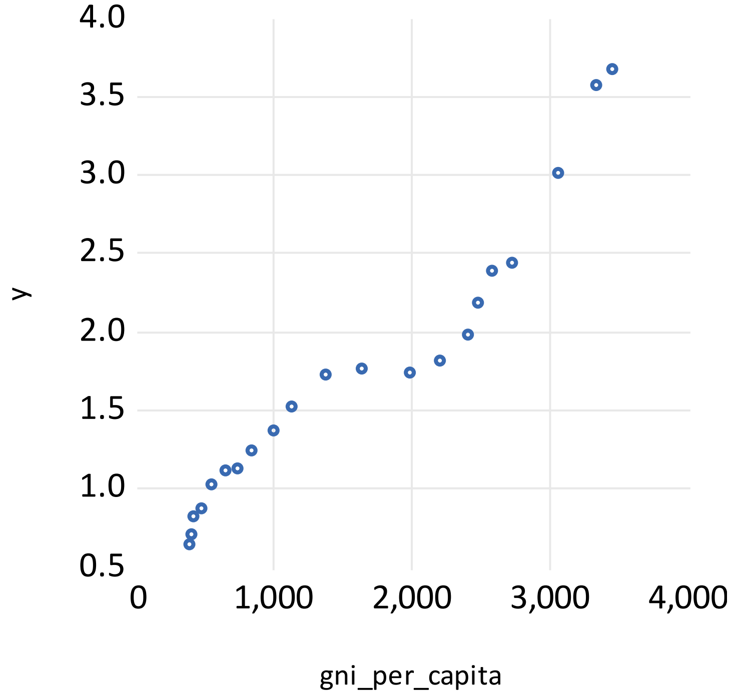
Singapore



Thailand



Vietnam



Discussion

The relationship between climate risk, CO_2 emissions, and economic complexity in ASEAN-5 reflects diverse trajectories shaped by each country's stage of development and degree of diversification. Rather than a uniform path, the region demonstrates a spectrum of approaches to balancing industrial growth with sustainability.

Indonesia illustrates the dynamics of a large, resource-rich economy that is actively pursuing downstream strategies to add value to commodities such as coal, palm oil, and nickel. While these sectors contribute to elevated emissions and climate pressures, Indonesia's ongoing efforts in industrialization and hilirization represent important steps toward structural transformation. The challenge lies in ensuring that these initiatives evolve into broader diversification, enabling the country to gradually reduce its dependence on carbon-intensive activities while strengthening resilience to floods, deforestation, and land degradation.

Vietnam, meanwhile, has achieved a mid-level position in economic complexity through integration into global supply chains, particularly in electronics and textiles. This diversification enhances resilience and positions Vietnam favorably within the region, though reliance on coal power and rapid industrialization continue to drive emissions. Its geographic exposure to typhoons and coastal flooding underscores the importance of accelerating the energy transition.

Thailand and Malaysia both demonstrate relatively higher ECI, supported by diversified manufacturing bases in automotive, petrochemicals, and electronics. Their industrial strength provides adaptive capacity and opportunities for innovation, yet the carbon intensity of these sectors sustains significant emissions. For both countries, the key challenge is to ensure that diversification translates into sustainability, balancing competitiveness with the need to green their industrial models.

Singapore stands out as an outlier, with its very high ECI reflecting a deliberate transition towards a knowledge-driven economy centered on services, innovation, and technology. This structural diversification away from traditional industry has reduced carbon intensity and strengthened adaptive capacity, even though the city-state remains physically vulnerable to sea-level rise. The reverse U-shaped trajectory observed in Singapore's emissions profile illustrates how a proactive embrace of knowledge-centric industries can support both sustainability and resilience.

Taken together, these national experiences suggest that diversification is a critical factor linking economic complexity with climate resilience. Countries at earlier stages of diversification, such as Indonesia, are laying the groundwork for transformation, while those with mid- to high-level complexity, such as Vietnam, Thailand, and Malaysia, must ensure that industrial strength evolves into greener practices. Singapore's example demonstrates the potential of structural transformation, showing how diversification into knowledge-based sectors can mitigate emissions and enhance resilience.

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